Spore production perpetuates the existence of moss. Great quantities of spores are produced during the life cycle of the plant.

Moss Eradication In Putting Green Turf

With persistence it can be selectively removed.

by KEITH A. HAPP

WITH ever-increasing demands placed on putting green turf, fueled primarily by the need for speed, is it any wonder that surface management problems develop? Today's golf course superintendent is faced with many turf management decisions, most of which are centered on providing the best possible playing conditions. At times during this quest, plant health is compromised in order to deliver the desired playing effect. While pursuing the ultimate ball roll and surface performance, bentgrass vigor can decline and the potential for weed development increases. One weed that can easily invade and fill available voids is moss. A small moss colony can proliferate and turn into a bigger problem that is more difficult to overcome. If conditions remain favorable, moss can spread across a putting surface.

It has been reported that thousands of species of moss exist. This is no surprise, since moss has been around for some 350 million years. Moss can develop and thrive in many different environments. Four mosses that often inhabit putting green turf are *Byrum argentum, Byrum lisae, Amblystegium trichopodium*, and *Brachythecium spp.* Each has its own characteristics. For example, *Byrum argentum* (silvery thread moss) is found in open sites. Its silvery appearance allows it to be distinguished easily from other mosses, and it is one of the most common contaminants of putting green turf.

Byrum lisae also is found in open sites but favors rocky or sandy soils. *Byrum lisae* is distinguishable from other mosses by its green to yellow-green appearance, and its colonies form tufts or clumps. Both species of *Byrum* mosses can tolerate a wide range of soil moisture conditions. A common misperception of *Byrum* moss is that it only competes well in shady, damp sites where turf has little or no chance of competing for space. Although it remains true that the best defense against weed encroachment is a dense stand of turf, *Byrum* moss can rapidly fill a void if the opportunity is presented. Once established, and if the conditions remain favorable, *Byrum* moss will proliferate in full sunlight.

Amblystegium trichopodium, on the other hand, is more difficult to identify and thrives in saturated soils. As such, this moss may be a problem on heavy clay soils or areas of poor drainage. *Brachythecium spp.*, which also thrives in wet soil conditions, is a common variety of moss referred to as "yard moss." *Amblystegium* and *Brachythecium* moss usually are found in higher cut turf, but they can be tracked easily into putting green surfaces. These mosses can become established in the rough or perimeter areas of the course and spores can be spread via air or foot traffic.

What is Moss?

Moss is a photosythesizing terrestrial plant. However, mosses are non-vascular plants and need to be in contact with water to avoid drying out. Many mosses absorb water over their whole surface, while others take in water through their rhizoids in a manner similar to that of vascular plants. Mosses that can survive in a state of desiccation have fine, hairlike leaves that can reflect the sun's heat. Cuticle development is rare, and this results in mosses being adapted to shady, moist locations. Mosses can, however, survive long periods of desiccation, in some cases several years, and can withstand high temperatures in a dormant state. Laboratory studies have found that mosses can tolerate dehydration levels equal to 80% of original biomass. When mosses are rehydrated, an immediate respiratory burst is manifested, but recovery is slow. Additionally, research has provided evidence that mosses can survive extended periods of dormancy by living symbiotically with blue-green algae. This relationship is important. Algae can be viewed as a precursor to moss encroachment. Hence, addressing the factors that encourage algae growth can preventatively discourage moss colonization. It is much easier to eradicate algae than it is to selectively remove moss from putting green turf.

How Does Moss Reproduce?

Although water is essential for their sexual reproduction, mosses are mainly land plants, and only a few species are adapted to aquatic environments. It is possible for moss to reproduce both sexually and asexually.

The sexual reproductive organs of bryophytes (mosses) are very characteristic in form, but they have little resemblance to those of flowering plants. Male and female organs may be on separate plants or on the same plant. In mosses the sex organs are usually interspersed with sterile hairs and are enclosed in leaves. This defense mechanism allows the moss to survive prolonged states of desiccation.

Asexual reproduction can be facilitated by water, wind, foot traffic, and even by maintenance equipment. For example, a moss plant can be severed by a golf spike and then transported to another area. When male and female gamete cells come in contact, fertilization is possible and a zygote is formed. Additionally, moss bryophytes can grow from small pieces of shoot or even leaves. Once a zygote is formed it is protected in specialized (gametophyte) tissue. The zygote then develops into the sporophyte, which eventually releases spores. The reproductive cycle is complete when these spores develop into the gametophyte structures that are identified as moss. Again, the primary requirements for completion of this cycle are voids in the turf and spores that easily generate a new colony.

Mosses develop in response to photosynthesis and also by nitrogen fixation in the absence of a light source. In the case of fixation, nitrate fertilizers applied to stimulate growth of the desired turf can be a catalyst for moss development. Thus, fertilization alone may not adequately correct a moss problem. To a certain degree, it could exacerbate the undesirable condition.

How Can Moss Be Identified?

Moss and slime/algae are different types of lower plants. It is relevant to consider them together because their occurrence and control measures overlap. When moss first colonizes an area it produces a black, slimy mat across the area before the green vegetative structures form. The green structures grow into branch-like filaments called protonema. These are the threadlike structures that bud out and develop into the gametophyte. The protonema of mosses are extensive, resembling green algae, and may persist for months. In the life cycle of moss, it is possible to wrongly diagnose and confuse this with algae. This is important and reinforces the need to have a basic understanding of the life cycle of moss. Accurate diagnosis leads to accurate and precise treatment of the problem at hand.

Mosses can take many shapes and forms. Stems and leaves of moss are complex, most having conducting strands, midribs, and a great diversity of cell form. Shoots develop from tetrahedral cells, and this results in three leaf arrangements. Leaves may be grouped in pairs, threes, and even sets of five. In the majority of mosses, leaves are not arranged in regular rows. Except for the midribs, leaves are one cell thick, with most or all of the cells containing chloroplasts. This particular feature can be exploited when eradication is attempted. Disrupting photosynthesis of moss via selective desiccation methods provides a competitive edge for turf, provided the desiccating effect is maintained.

Mistakenly treating for algae may interrupt photosynthesis, but in the case of mosses it has been shown that they will reproduce in the absence of light. Furthermore, not even soil sterilization can guarantee that an area will be free of dormant moss spores. The dried-out vegetative state does not utilize water or nutrients but will allow reproduction when conditions are again favorable. This further indicates the need to be persistent with control measures. Control requires constant vigilance and an understanding of when infestation takes place. Basically, if moss has colonized an area, an ongoing eradication program is needed to assure that it will not continue to be a problem.

The First Step in Correcting the Problem

First, ask why moss has developed on the green. Take a step back and review the management practices currently in use.

- Are surface and subsurface drainage systems sufficient to handle moisture conditions?
- Are cutting heights too low?
- Are fertilizer levels so low that they are preventing turf growth?
- Are the nutrients within the soil in balance so as to provide an optimal environment for sustained turf growth?
- Has a topdressing change been made that could affect the manner in which water moves through the soil profile?
- Finally, has irrigation frequency changed and inadvertently become a causal factor of moss development?

Answering these questions could provide a solution to moss encroachment problems and insight as to why colonization occurred.

To many, the solution may sound simple: raise cutting heights and increase fertility to promote healthy turf. But will contemporary golfers accept slower putting green speeds? From my experience, the answer is "no." A holistic approach, combining cultural and chemical means, may provide a more acceptable answer.

Cultural Strategies

A strong cultural management program can help to reduce the potential for moss encroachment. For example, aeration is the cornerstone of many maintenance programs. Aeration in any form helps to improve infiltration rates, which in turn helps to dry the soil surface and provides a competitive edge to the desired turf. Physically removing thatch may also provide assistance in defeating moss populations. The fact is, small-tine shallow aerification has gained wider acceptance by both turf managers and golfers. Small-tine aeration, such as with quadratines, provides agronomic benefit without creating a great deal of surface disruption, and it is an excellent proactive management strategy whether moss is present or not.

In combination with small-tine aeration, light and frequent topdressing applications are a common practice. On heavy soil greens, the main benefit realized from this maintenance strategy is increased water infiltration. Basically, a green with better surface characteristics is being established on top of a native soil material. On new USGA greens or other high-sand-content greens, the benefit realized is good thatch management. To maintain a balance of water and air in the profile, and particularly near the soil surface, the thatch must be constantly diluted. As soil porosity increases, so does the likelihood that moss encroachment can be brought under control. Allowing the moisture to move freely into the soil rather than remaining on the surface reduces the potential for moss development. Also, as topdressing is applied, moss spores that may be present near the surface will be buried.

Examining changes in topdressing materials may offer clues as to why moss encroachment has occurred. Changes in the particle size of the topdressing sand or the use of a different organic matter in the mix could produce long-term problems. Periodic sampling and testing by a qualified physical testing laboratory can add both a check and a great deal of peace of mind. Problems can be avoided when a strong quality control program is in place.

A balance between cutting heights and fertility levels must be established. The overall goal of any maintenance plan is to provide healthy, vigorous turf. If this maintenance plan is compromised for the sake of ultra-fast green speeds, then weed invasion should be expected. It has been observed that moss growing on a putting surface will not encroach into the surrounding collar area. Quite simply, turf cut at a greater height resists invasion. Raising the mowing height as little as 1⁄32" has shown positive effects in reducing moss populations. Even raising the height of cut from 1⁄8" to 9⁄64" provides 13% more leaf blade. Greater leaf blade surface area enables the turf to become more vigorous by increasing photosynthesis. There are many other tools available to manage putting green speeds. Growth regulators, for example, can be applied in combination with other grooming tactics to enhance surface performance.

If conditions are favorable, moss can spread across a putting green and be carried from surface to surface. A small moss colony can proliferate and turn into a bigger problem over time.

Fertility

A Scottish greenkeeper once said, "Moss is a sign of poverty in the soil." This is an amazingly accurate statement that has been verified by university research. There are some distinct nutrient deficiencies and relationships that favor moss encroachment. Research indicates that calcium-rich soil may exacerbate *Byrum* moss development. Areas of moss colonization tend to have higher calcium-to-magnesium ratios and a higher percentage of silt and clay in the surface. This soil texture accounts for the increased water retention due to reduced percolation. Examining the nutrient status and the physical properties of the soil therefore may provide a great deal of information not only to defeat moss, but also to promote the healthiest stand of turf possible. If calcium levels are high, $MgSO_4$ (Epsom salt) treatments may be warranted. Magnesium is a component of chlorophyll production, and its addition into the soil could enhance turf vigor.

There is a correlation between moss populations and potassium (K) levels in the soil. Moss pressure seems to increase as K levels decrease. As such, monitoring K levels in the soil is important. If deficiencies exist, corrective applications can be made in the spring or fall. Sulfate-of-potash treatments provide a safe means to achieve adequate K levels.

Various fertilizer treatments have been applied to selectively retard moss growth while the desired turf is promoted. Ammonium sulfate, for example, has performed well in many studies. This fertilizer is thought to produce a selective desiccating effect on moss when applications are made frequently and at low dosage rates. Treating with 1⁄12 to 1⁄8 lb. of N/1000 sq. ft. per week can produce positive results. This treatment regime also provides an acidifying effect that can produce desirable side effects. Patch diseases may be less likely to develop when the pH of the soil is managed in this manner.

Ferrous sufate applications have also been closely examined for their effect on moss. In fact, in 1933 calcined iron sulfate was a common treatment for moss problems. Iron treatments, in the form of iron sulfate, can be applied at a rate of 2 ozs./1000 sq. ft. every other week during the summer or at higher rates during the fall and winter. Up to 3 lbs. of iron sulfate/1000 sq. ft. has been applied to moss-infested putting greens, and this treatment strategy remains common in the British Isles. The effect of the treatment is dramatic. The turf takes on a dark green or even black appearance due to the chlorophyll surge. Moss colonies may experience a selective desiccating effect and the turf recovers. Positive signs of the desiccating effect on moss are exhibited by an orange-brown or golden-brown coloration. This is the initial sign of moss decline, but it is by no means an indication that treatment strategies should stop. As previously stated, persistence is the key.

Hydrated lime and copper sulfate have been suggested as treatments for moss contamination problems. However, the effect on the pH of the soil is of greater concern regarding the use of lime, and copper sulfate applications do not offer a wide margin for error. In many instances, the results of the treatment may be worse than the original problem.

Potassium of fatty acid (DeMoss) is a labeled product for moss control. The treatment procedure is similar to that of ammonium sulfate applications. The material must be applied frequently over an extended period of time to achieve the desired effect. Applying 2 to 3 ozs. of material/1000 sq. ft. every week can produce a significant reduction in moss populations, and the consistency with which the material is applied is an important ingredient for success.

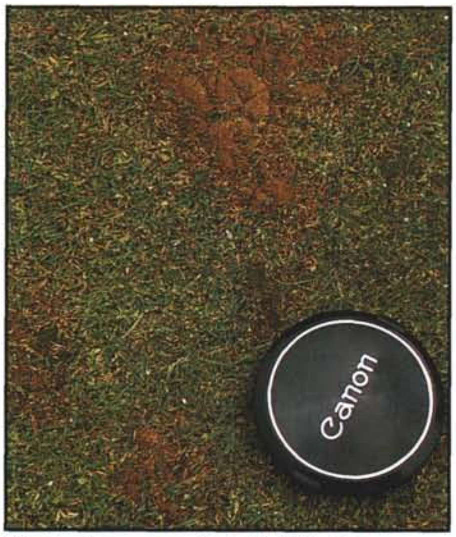
Chemical Treatments

Timing of chemical applications appears to be crucial to their success. Studies have tested control measures during maximum sporophyte development in the spring and found that selective eradication can be achieved.

Maneb- or Zineb-based fungicides applied to moss during its early stages are phytotoxic to young/immature moss plants and algae. Also, there are indications that Maneb treatment may inhibit N-fixation with respect to the symbiotic relationship of moss and algae. Treatments render populations unable to produce carbohydrate reserves and thus unable to compete for space. Maneb is a broad-spectrum fungicide, but it produces herbicidal action favorable to moss control.

Case Studies in Moss Control: Case Study #1

Spot treatment procedures have also provided satisfactory control of moss. DeMoss (Mycogen Corporation) has been applied in combination with wetting agents and a surfactant. Todd Voss, of the Double Eagle Golf Club, experimented with a combination of materials, which included DeMoss, on



Moss also responds to fertilization. A blackening of the moss often does not sufficiently desiccate the moss colony. Fertilization must be persistently employed to achieve the desired result.

his sod nursery. The initial goal was to find a mixture that would apply selective pressure to moss without harming the desired stand of bentgrass. Once satisfactory results were achieved, the spray combination (1 oz. DeMoss, 1 oz. Lesco Wet, 1 oz. spreader sticker in 32 ozs. of water) was applied to moss populations on the course. Treatments were performed in the afternoon during the summer and continued throughout the fall. The treatments were performed with a hand-held squirt bottle calibrated to deliver repeatable applications.

Three to four squirts from the spray bottle adequately soaked the moss colonies. Within 24 to 48 hours, moss populations exhibited the orange to orange-brown color, signifying that a positive desiccating effect had occurred. Repeat treatments were performed depending on the density of the moss colonies and the spore populations in the soil. Minor phytotoxic effects were exhibited on the turf. But, via fertilization, the turf grew out of the herbicidal effect caused by the moss control mixture.

In combination with this eradication technique, spiking and overseeding were performed. As bentgrass populations increased, interspecific competition increased, and moss colonization was minimized.

Case Study #2

Another treatment strategy that has shown promising results is the use of Dawn dishwashing detergent. The detergent provides an excellent selective desiccating effect on moss populations and due to the ingredients of the product may also provide cryptocidal effects on the moss spore populations in the soil. Although Dawn has been tested at universities (Danneberger 1998, Landschoot 1998) and used successfully on golf courses, it is not currently labeled for use for moss control on turf and thus is not legal for this use at the present time.

John Keeler, of Hershey's Mill Golf Club, experimented with a number of control techniques on a designated test site. Applications of iron sulfate were tested at various rates, in addition to Dawn treatments. A check plot was also established to better evaluate treatment performance. Dawn treatments ranged from 2 ozs. to 8 ozs. of material/1000 sq. ft. The product was delivered to the moss colonies with a minimum of 1 gal. of water/1000 sq. ft.

An immediate response was observed following the application of Dawn. First, a water-soaked appearance was observed in the treated areas. Within 48 hours the moss colonies exhibited the classic orange or orange-brown discoloration while the surrounding turf showed no signs of phytotoxicity. After testing was formed, the material was applied to moss-infested sites throughout the course, and within a four- to six-week period acceptable moss control was achieved.

Although the treatment strategy centered on Dawn applications, a holistic program was put in place. Topdressing was applied periodically and nitrogen treatments were made on a routine interval. Putting green speeds were maintained in the sufficient range with the use of walk-behind mowers and infrequent rolling. Irrigation was applied to support turf growth, but not to the point of overly saturating the soil profile. Basically, every effort was put forth to strengthen the basic agronomic programs in order to allow moss control techniques to be as effective and long-lasting as possible. Surface performance was improved, and this led to heightened golfer enjoyment.

Case Study #3

John Klosiewicz, of the Vic Meade Hunt Club, utilized a combination of methods to overcome a serious moss infestation problem. The problem was so bad that reconstruction was thought to be the only corrective procedure available.

The road to recovery began with height-of-cut adjustments. The mowers were raised to 5/32". Fertility levels were also increased, with ammonium sulfate and urea being the main sources of nitrogen. Chemical analysis of the soil provided evidence that high soluble salt problems existed, and this was addressed by treating with magnesium sulfate and gypsum.

The chemical analysis led to questions about how the salt problems developed. To find answers, the topdressing material was submitted for both chemical and physical analysis. The results indicated that the topdressing was a contributing factor due to its moisture retention capacity. A program of aggressive aeration was implemented to help remove thatch and soil. Following aeration, a carefully selected straight sand topdressing was applied to fill newly created columns to the surface. This was supplemented by weekly treatments of between 50 and 100 lbs. of material/1000 sq. ft. throughout the season. Soil porosity improved dramatically and this allowed the surfaces to be maintained in a much drier state.

After the physical properties of the soil were addressed, the next step was to selectively attack the moss colonies on the greens. During the months of December and February, iron sulfate was applied at a minimum rate of 2 lbs. of material/1000 sq. ft. This began the selective desiccation process. As the spring weather arrived and soil temperatures increased, urea and ammonium sulfate products were rotated into the treatment regime. Each was applied at a rate of 1/8 lb. N/1000 sq. ft. per week. The bentgrass responded to the increased N level and the moss became much less prevalent. Still, another method of eradication was needed.

In combination with fertility adjustments, DeMoss was applied every other week at a rate of 1 to 2 ozs. of material/1000 sq. ft. Only severely infested greens were treated in this manner, while spot treatments were performed on greens that exhibited only minor infestation. Bentgrass seed was introduced regularly during the entire eradication process. This integrated approach to moss control paid off; non-target damage was minimized and bentgrass populations increased dramatically.

Using a combination of techniques, the moss problems were brought under control in seven months. During this time, the playability of the surfaces did not suffer. Multiple mowings, light and frequent topdressing, growth regulation treatments, and rolling were used to maintain acceptable conditions.

Conclusion

The control of moss should be approached as a long-term project. It takes time for moss to develop into colonies that both visually and physically affect the playability of greens. Therefore, it is reasonable to expect that it will take time, often a long time, to reverse the undesirable condition.

The immature stage of moss colonization (the protonema) is highly susceptible to desiccation. If properly diagnosed during this early stage of development, site-specific treatment performed in a carefully thought-out manner could provide excellent results. Cultural practices such as spiking, aerification, topdressing, overseeding, and proper fertilization should accompany the use of a selective eradication product.

All aspects of management should be considered when battling moss. Is the sunlight sufficient to allow the turf to compete and fend off invasions? Is the air movement around the problem area adequate to permit soils to be purged of excessive moisture? Drainage should be corrected or installed where it is inadequate or nonexistent. Deep-tine aerification can provide relief when compacted soil conditions exist. Thatch management will enable good rooting and thus increase the vigor of the turf. Any preventative measure should be done with the overall goal being to promote healthy, vigorous turf. After all is said and done, healthy turf is the only way to cure and prevent moss invasion.

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